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## TDR Tutorial - Introduction to Time Domain Reflectometry

### An Introduction to Time Domain Reflectometers

Time Domain Reflectometers have been around for many years and remain the fastest, most accurate way to pinpoint cabling problems.

Historically, the TDR has been reserved for only large companies and high level engineers. This was due to the complexity of operation and high cost of the instruments. The TDR has been greatly under utilized.

Riser-Bond Instruments recognized these shortcomings and developed the first "little TDR" in the early 1980s. The simplified digital TDR has now become a standard tool for the first level technician. Riser-Bond Instruments' complete product line has been permeated by the concept that test equipment should be simple, accurate, user-friendly, rugged, and high value for the cost.

Due to advances in today's technology, the operation and interpretation of a TDR have been greatly simplified. Because of its ability to identify cable problems, the TDR is now rapidly regaining popularity throughout communications industries.

If a cable is metal and it has at least two conductors, it can be tested by a TDR. TDRs will troubleshoot and measure all types of twisted pair and coaxial cables, both aerial and underground.

TDRs are used to locate and identify faults in all types of metallic paired cable. TDRs can locate major or minor cabling problems including; sheath faults, broken conductors, water damage, loose connectors, crimps, cuts, smashed cables, shorted conductors, system components, and a variety of other fault conditions. In addition, TDRs can be used to test reels of cable for shipping damage, cable shortages, cable usage, and inventory management.

The speed and accuracy of the time domain reflectometer makes it today's preferred method of cable fault location. Although today's instruments are more user friendly, a good understanding of the basic principles and applications of a TDR is essential to successful troubleshooting. Like all new equipment, getting to know the instrument and its operation makes the TDR a more valuable tool.

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### Principles of Operation

The TDR works on the same principle as radar. A pulse of energy is transmitted down a cable. When that pulse reaches the end of the cable, or a fault along the cable, part or all of the pulse energy is reflected back to the instrument.

The TDR measures the time it takes for the signal to travel down the cable, see the problem, and reflect back. The TDR then converts this time to distance and displays the information as a waveform and/or distance reading.

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## TYPES OF TDRs

There are two ways a TDR can display the information it receives. The first and more traditional method is to display the actual waveform or "signature" of the cable. The display, which is either a CRT or an LCD, will display the outgoing (transmitted) pulse generated by the TDR and any reflections which are caused by impedance discontinuities along the length of the cable.

The second type of display is simply a numeric readout which supplies the distance indication in feet or meters to the first major reflection caused by an impedance change or discontinuity. Some instruments also display if the fault is an OPEN or SHORT indicating a HIGH IMPEDANCE change or a LOW IMPEDANCE change respectively.

Traditional Waveform TDRs supply more information than do the digital numeric versions. However, the simplified digital models are less expensive and easier to operate. Costing only a fraction of a traditional TDR, many simplified digital TDRs are just as accurate and can locate most major cable faults.

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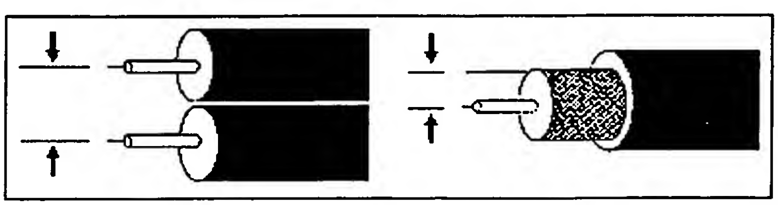
## IMPEDANCE

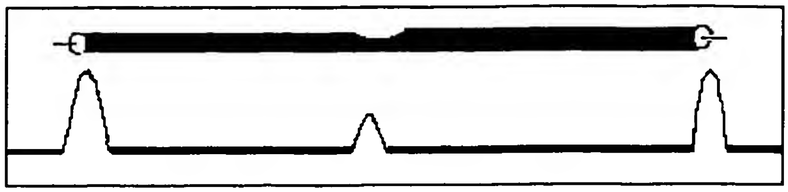
Any time two metallic conductors are placed close together, they form a cable impedance. A TDR looks for a change in impedance which can be caused by a variety of circumstances, including cable damage, water ingress, change in cable type, improper installation, and even manufacturing flaws.

The insulating material that keeps the conductors separated is called the cable dielectric. The impedance of the cable is determined by the spacing of the conductors from each other and the type of dielectric used.



If the conductors are manufactured with exact spacing and the dielectric is exactly constant, then the cable will be constant. If the conductors are randomly spaced or the dielectric changes along the cable, then the impedance will also vary along the cable.

A TDR sends electrical pulses down the cable and samples the reflected energy. Any impedance change will cause some energy to reflect back toward the TDR and will be displayed. How much the impedance changes determines the amplitude of the reflection.



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**PULSE WIDTHS**

Many TDRs have selectable pulse width settings. The larger the pulse width, the more energy is transmitted and therefore the further the signal will travel down the cable. Pulse widths may include 2 nsec, 10 nsec, 100 nsec, 1000 nsec, 2000 nsec, and 4000 nsec. A TDR may contain only one or all of the pulse width settings.

NOTE: Even when testing very long lengths of cable, always start the fault finding procedure in the shortest pulse width available, as the fault may be only a short distance away. If the fault is not located, switch to the next larger pulse width and retest. Keep switching to the next larger pulse until the fault is located.

Sometimes larger pulse widths are helpful even for locating faults that are relatively dose. If the fault is very small, the signal strength of a small pulse may not be enough to travel down the cable, " see" the fault, and travel back. The attenuation of the cable combined with the small reflection of the partial fault can make it difficult to detect. A larger pulse width would transmit more energy down the cable, making it easier to see the small fault.

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**BLIND SPOTS**

The pulse generated by the TDR takes a certain amount of time and thus distance to launch. This distance is known as the blind spot. The length of the blind spot varies with the pulse width. The larger the pulse width, the larger the blind spot.

It is more difficult to locate a fault contained within the blind spot. If a fault is suspected within the first few feet of cable, it is advisable to add a length of cable between the TDR and the cable being tested. Any faults that may have been hidden in the blind spot can now easily be located. When adding a length of cable to eliminate the blind spot, remember the TDR is also reading the length of this jumper cable. The length of the jumper must be subtracted from the cable when measuring from the point of connection.

It is best if the jumper cable is the same impedance as the cable under test. The quality of the connection is an important factor regardless of the type of connection or jumper being used.

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**VELOCITY OF PROPAGATION (VOP)**

The TDR is an extremely accurate instrument. However, variables in the cable itself sometimes cause errors in distance measurements. One way to minimize error is to use the

correct Velocity of Propagation (VOP) of the cable under test. The VOP is a specification of the cable indicating the speed at which a signal travels down the cable. Different cables have different VOPs. In order to assure the most accurate distance measurements, the cable VOP must be determined.

VOP Defined: The speed of light in a vacuum is 186,400 miles per second. This speed is represented by the number 1 (100%). All other signals are slower. A cable with a VOP of .85 would transmit a signal at 85% of the speed of light. A twisted pair cable, which typically has a lower VOP (such as .65), can transmit a signal at 65% of the speed of light.

The VOP number of a cable is determined by the dielectric material that separates the two conductors . In a coaxial cable, the foam separating the center conductor and the outer sheath is the material determining the VOP. In twisted pair, the VOP number is determined by the spacing between the plastic.

Knowing the VOP of a cable is the most important factor when using a TDR for fault finding. By entering the correct VOP, the instrument is calibrated to the particular cable. Typically, the VOP of the cable under test will be listed in the cable manufacturer's catalog or specification sheet. If not, simply measure a length of good cable (no faults) and change the TDR's VOP setting until the display shows the same distance reading as the measured length. The VOP of a cable can change with temperature and age. It can also vary from one manufacturing run to another. Even new cable can vary as much as +/- 3%.

One might think the variations in VOP would make it almost impossible to locate a fault accurately. Fortunately, there are ways to minimize the error in the VOP when testing a faulted cable, resulting in very accurate distance measurements. These techniques do not work when testing or measuring good (no fault) cable.

The most common technique used to reduce VOP error is to test the faulty cable from both ends. The procedure is as follows:

Determine the path of the cable. With a Measuring wheel or tape, measure the exact length of the cable being tested. Set the VOP according to the manufacturers specifications, test the cable from one end, and record the distance reading. Next, using the same VOP setting, test from the opposite end of the cable and record. If the sum of the readings is the exact length of the cable that was measured, the VOP is correct and the fault has been located.

If the sum of the two readings is more than the measured distance, reduce the VOP setting and re-test. If the sum of the two readings is less than the measured distance, increase the VOP setting. In this case, the operator must also consider the possibility of two faults.

The same result can be obtained mathematically. Take the actual cable length and divide by the sum of the two TDR readings obtained by the tests from each end . This gives the adjustment factor. Then multiply each of the TDR readings by the adjustment factor. This result will be the corrected length readings.

A partial listing of cable types and their Velocity of Propagation.

| CABLE TYPE | TYPE | VOP |
|---|---|---|

| | | |
|---|---|---|
| **TELEPHONE** | | |
| 19 AWG | Gel-Filled | 68 |
| 22 AWG | Gel-Filled | 66 |
| 24 AWG | Gel-Filled | 62 |
| 26 AWG | Gel-Filled | 60 |
| 19 AWG | AIR | 72 |
| 22 AWG | AIR | 67 |
| 24 AWG | AIR | 66 |
| 26 AWG | AIR | 64 |
| | Polyethylene | 66 |
| | Polypropylene | 66 |
| | Teflon | 69 |
| | PIC | 67 |
| | Pulp | 72 |
| **CATV** | | |
| **Belden** | Foam | 78S-82 |
| | Solid | 66 |
| **Comm/Scope** | (F) | 82 |
| PARA I | | 82 |
| PARA III | | 87 |
| QR | | 88 |
| **Times Fiber** | RG-59 | 93 |
| T4,6,10,TR+ | | 87 |
| TX, TX10 | | 89 |
| Dynafoam | | 90 |
| Trilogy | (F) | 83 |
| 7 SERIES | | 88 |
| **CapScan** | FOAM | S2 |
| CC SS | | 88 |
| **CZ Labs** | FOAM | 82 |
| **General Cable** | RG-59 | 82 |
| MC2 | | 93 |
| **Scientific Atlanta** | RG-59 | 81 |
| Trunk | | 87 |

| | | |
|---|---|---|
| **LAN** | | |
| UTP 26 | | 64 |
| Thinnet | | 66-70 |
| Ethernet | | 77 |
| Token Ring | | 78 |
| Arcnet | | 84 |
| Twinaxial | AIR | 80 |
| Twinaxial | | 71 |
| Appletalk | | 68 |
| **IBM** | | |
| Type 1 | | 64 |
| Type 2 | | 66 |
| Type 3 | | 70 |
| Type 4 | | 72 |
| Type 5 | | 76 |
| Type 6 | | 78 |
| Type 7 | | 82 |
| Type 8 | | 84 |
| Type 9 | | 82 |
| **LAND/MOBILE** | | |
| **ANDREW** | | |
| RADIAX | All | 79 |
| **HELIAX** | | |
| FHJI-50 | 1/4" | 79 |
| FSJI-50 | 1/4" | 78 |
| FSJ4-50B | 1/2" | 81 |
| LDF2-50 | 3/8" | 88 |
| LDF4-50A | 1/2" | 80 |
| LDF4-75 | 1/2" | 88 |
| LDF5-50A | 7/8" | 89 |
| LDF7-50 | 1 5/8" | 88 |
| FT4-50 | 1/2" | 85 |
| FT5-50 | 7/8" | 89 |
| HJ4-50 | 1/2" | 91 |
| HJ5-50 | 7/8" | 92 |
| HJ5-75 | 7/8" | 90 |
| HJ7-50A | 1 5/8" | 92 |

| | | |
|---|---|---|
| HJS-50B | 3" | 93 |
| HJ11-50 | 4" | 92 |
| HJ9-50 | 5" | 93 |
| **CABLEWAVE** | | |
| FLC12-50J | 1/2" | 88 |
| FLC78-50J | 7/8" | 88 |
| **CABLEFLEX** FOAMFCC + FLC | | |
| FCC 38-50J | 3/8" | 81 |
| FLC 12-50J | 1/2" | 88 |
| FLC 78-50J | 7/8" | 88 |
| FLC 158-50J | 1 5/8" | 88 |
| **CABLEWAVE** | ALL | 88 |
| **COAX** TRANSMISSION LINE | | |
| 920213 | 7/8" | 99 |
| 920214 | 1 5/8" | 99 |
| **FLEXWELL** HCC | | |
| HCC12-50J | 1/2" | 91 |
| HCC7S-50J | 7/8" | 91 |
| HCC15S-50J | 1 5/8" | 95 |
| HCC300-50J | 3" | 96 |
| HCC312-50J | 3 1/2" | 96 |
| HF41/2CU24 | 4 1/2" | 97 |

| TDR Principles of Operation | Usage Techniques | Waveform Analysis |
| General | CATV | Telephone | Broadcast | Cellular | 2-Way Radio | Power | LAN/WAN |
| Dual Twisted Pair and Coax TDR | Dual Twisted Pair TDR | Coax TDR | Basic Numeric TDR |

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